EE5103 Computer Control Systems: Homework #3
(Due date: 15/10/2023)

Q1. (10 Marks)
Consider the system given by the transfer function

$$H(z) = \frac{z + 0.9}{z^2 - 2.5z + 1}$$

Use polynomial design to determine a controller in the form of

$$R(q)u(k) = T(q)u_c(k) - S(q)y(k)$$

such that the closed-loop system has the characteristic polynomial

$$A_m(z) = z^2 - 1.8z + 0.9$$

Let the polynomial $A_o(z)$ have as low order as possible and place all of its poles in the origin. Design the controller such that the steady-state gain from the command signal $u_c(k)$ to the output $y(k)$ is one. Consider the following two cases:

a) The process zero is canceled.

(4 Marks)

b) The process zero is not canceled.

(4 Marks)

Simulate the step responses of the two cases (letting $u_c(k) = 1$), and plot out the corresponding output and input signals. Discuss the differences between the two controllers. Which one should be preferred?

(2 Marks)

Q2. (10 Marks)
Assume that the process is described by the transfer function

$$H(z) = \frac{z - 0.8}{z^2 - 4z + 4}$$

The reference model is specified as

$$H_m(z) = \frac{1}{z^2}$$

a) Design a controller in the form of

$$R(q)u(k) = T(q)u_c(k) - S(q)y(k)$$

to make the closed-loop transfer function match the reference model as close as possible. Also try to make the controller reject constant disturbance.

(5 Marks)

b) Design a two-degree-of-freedom controller in the form of

$$u(k) = u_{fb}(k) + u_{ff}(k)$$

where the feedback control signal $u_{fb}(k)$ is generated by the feedback controller

$$U_{fb}(z) = -\frac{S(z)}{R(z)}Y(z)$$

and the feed-forward control signal $u_{ff}(k)$ is produced by the feed-forward controller

$$U_{ff}(z) = H_{ff}(z)U_c(z)$$

Design the feedback controller and feed-forward controller properly to follow the same reference model and to reject constant disturbance.

(5 Marks)

Q3. (20 Marks)

Consider a vehicle, which has a weight m = 1000 kg. Assuming the average friction coefficient b= 200. Let y denote the displacement of the vehicle, then the dynamics of the vehicle can be described by the following equation

$$m\ddot{y}(t) + b\dot{y}(t) = u(t)$$

where m=1000, and b=200. Assume that the sampling period is 0.5s.
Design a two-degree-of-freedom digital controller in the form of

$$R(q)u(k) = T(q)u_c(k) - S(q)y(k)$$

to meet the following performance requirements on its step response for position control system:

1. The overshoot is less than 10%.

2. The settling time is less than 10 s.

3. The controller can reject the influence of unknown constant disturbance.

Q4. (10 Marks)

A nonlinear process is described by the input-output model

$$y(k+1) = y(k) + \frac{cu(k-1)}{y^2(k-1)+1}$$

where c is a constant parameter.

a) Design a one-step-ahead controller to make the output of the system, $y(k)$, follow any arbitrary desired output, $r(k)$.

(7 Marks)

b) Discuss the condition on the parameter c such that perfect tracking is attainable.

(3 Marks)